

Bridges Design Diploma

By EngoSoft training center

By Eng. Amr Ali
Bridges/Structural Engineer



About the instructor



➤ Biography:

- I have over 8 years' experience in bridges design, and roadway design both conceptual, detailed design review and project management.
- I work professionally on Revit structure, CSI Bridge, SpColumn, excel spreadsheets AutoCad structural bridge design.
- I am familiar with international standards such as AASHTO LRFD, EuroCode & Egyptian code of bridges.



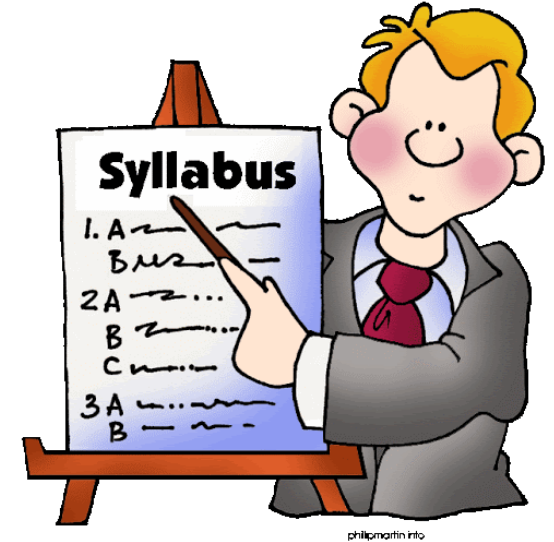
➤ Design Skills:

- Design of all types of bridges.
- Make conceptual design and detailed design drawings of bridges.

What is the content of this course

➤ Chapter 1 (Introduction):

- What is bridges ?
- What is the Importance of the bridges.
- Bridge Design stages (phases).
- Design codes and specifications.
- Types of bridges.
- Statical system of each type.
- Elements of bridges and their definitions.
- How loads transfer in bridges.

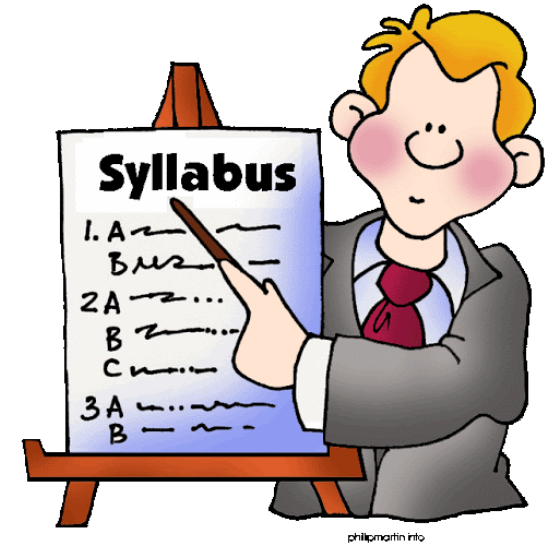


What is the content of this course

➤ Chapter 2 (different loads on the bridges):

1- Permeant loads:

- Dead loads (own weight, Parapet & and all non structural components .. etc.)
- Wearing Surface and utilities.
- Earth Pressure and earth fill.
- Prestressing load and secondary effect of prestressing.
- Force effects due to creep.
- Force effects due to shrinkage

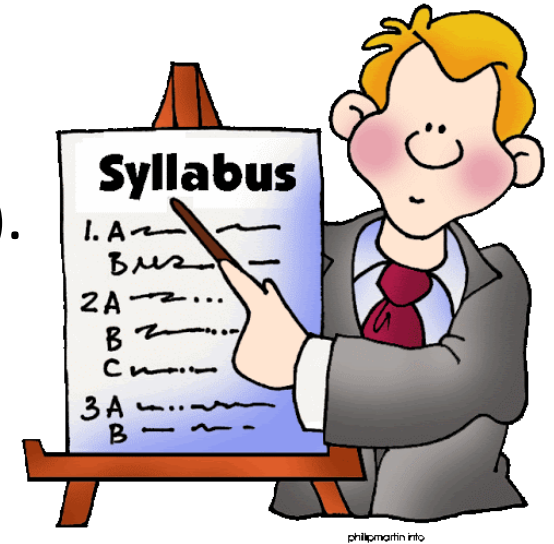


What is the content of this course

➤ Chapter 2 (different loads on the bridges, cont.):

2- Transient loads:

- Live loads on bridges according to different codes (Vehicle load).
- Braking load.
- Centrifugal load.
- Dynamic allowance (Impact).
- Temperature load (uniform and gradient different).
- Wind loads (on structure and on live load).
- Earth quake (seismic).

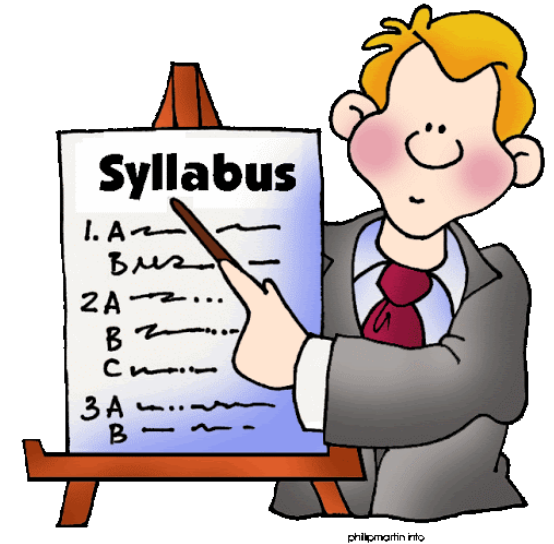


What is the content of this course

➤ Chapter 2 (different loads on the bridges, cont.):

2- Transient loads:

- Vehicular collision force.
- Pedestrian live load.
- Force effect due to settlement.



What is the content of this course

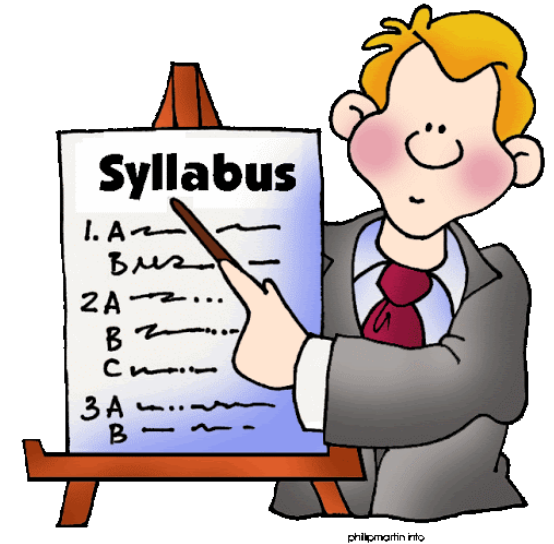
➤ Chapter 2 (Load Factors and Load Combinations):

1 – Service Load Combinations.

- Service I.
- Service III.

2 – Ultimate load combinations.

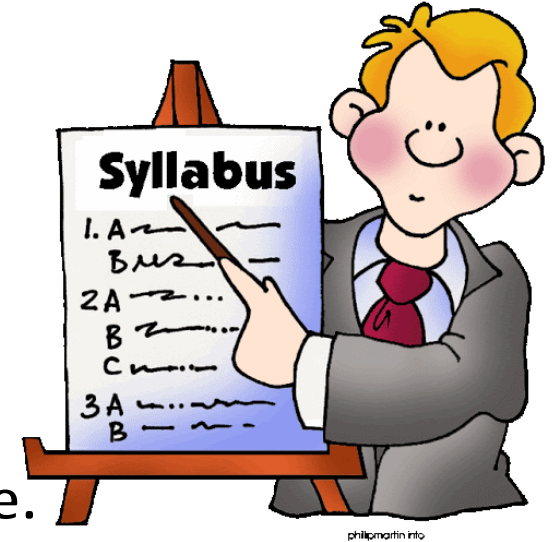
- Strength I.
- Strength III.
- Strength V.
- Extreme Event I (Earth Quake Combination).
- Extreme Event II (Vehicle collision combination).



What is the content of this course

➤ Chapter 3 (Conceptual Design):

- Different types of structural system of the bridges.
- Limitation of each system.
- Geometrical design and choose of the Supports location.
- How to choose the most suitable structural system of the bridge.
- Geometrical design and elements structural sizing.
- Bridges design from aesthetical point of view.



What is the content of this course

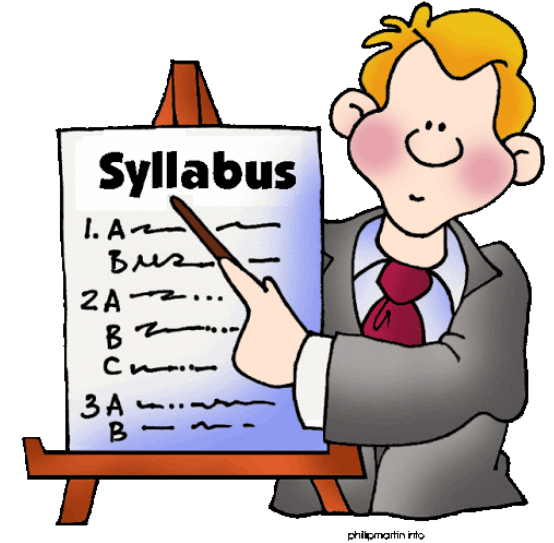
➤ Chapter 4 (Bridge component definition):

1- Substructure:

- Piles.
- Pile cap.
- Piers.
- Abutment.
- Bearings.

2- Superstructure:

- Bridge deck and its components (diaphragm and bridge deck).



What is the content of this course

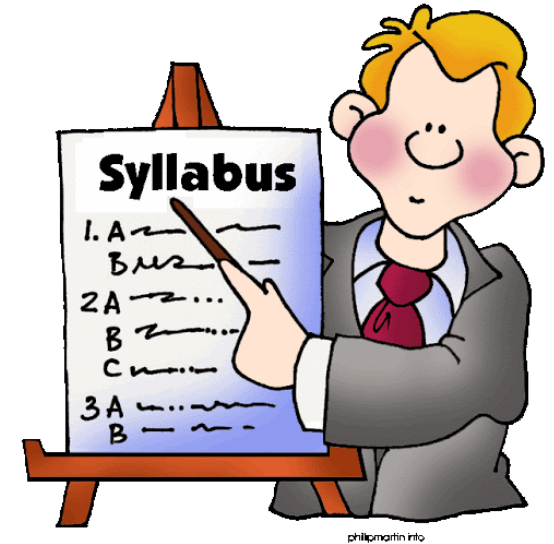
➤ Chapter 5 (Bridge relative to Transportation design):

1- Horizontal alignment:

- Bridge alignment.
- Define Bridge width.

2- Vertical alignment:

- Bridge profile.
- Super elevation.
- Check vertical clearance.



What is the content of this course

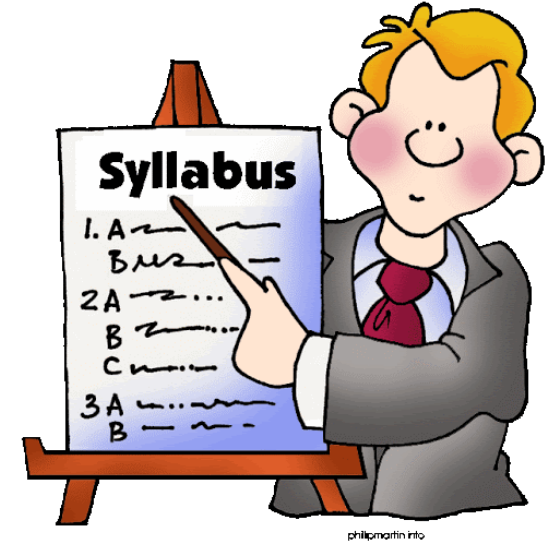
➤ Chapter 6 (Bridge General Arrangement Drawings):

1- Abutment:

- Bridge abutment general drawings.
- Bearing initial sizing and plinth dimensions.
- How to calculate abatement levels with respect to bridge dimensions and transportation profile/super elevation.

2- Pier:

- Pier initial size design.
- How to calculate pier level, plinth dimensions in girder bridges.

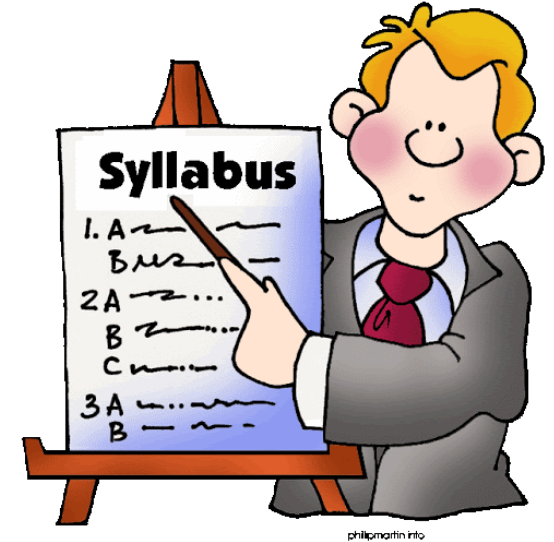


What is the content of this course

➤ Chapter 6 (Bridge General Arrangement Drawings):

3- Foundation:

- Foundation type.
- Calculate foundation size in case of shallow foundation.
- Calculate number of piles in case of deep foundations.
- Foundation size check under different load combinations (strength, earth quake & wind).
- Pile bent & mono piles definition and how to estimate size before implement soil structure interaction.

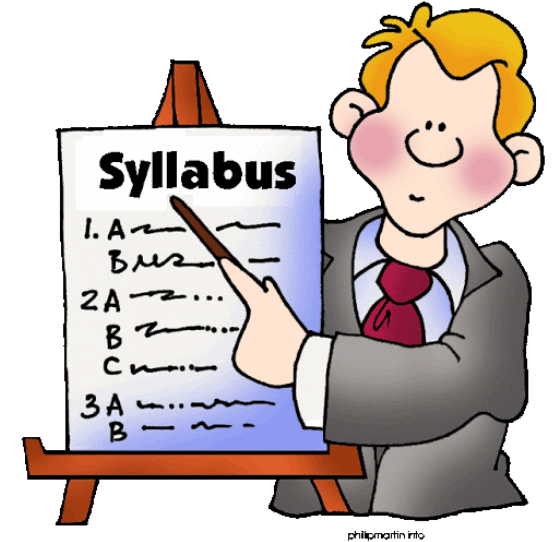


What is the content of this course

➤ Chapter 6 (Bridge General Arrangement Drawings):

4- Bridge deck:

- What we need to present in deck general drawings.
- How to make full general arrangement drawing of the bridge deck.
- How to size the different bridge deck component.
- The bridge transverse element initial check and sizing.



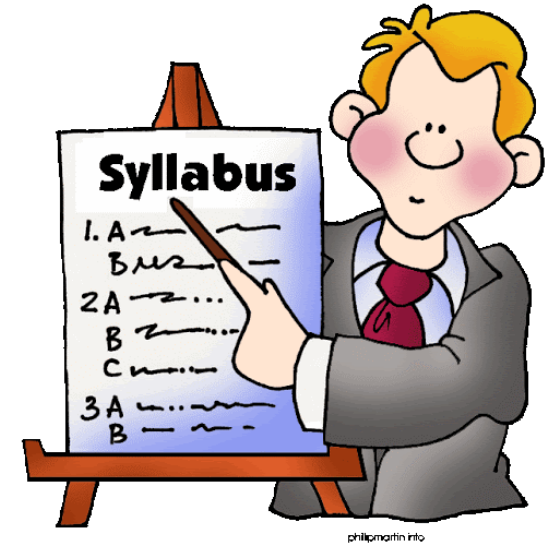
What is the content of this course



➤ Chapter 7 (CSI Bridge Software):

1- Input bridge data:

- Alignment.
- Live load Lanes.
- Live load vehicle diffination.
- Materials properties.
- Deck section.
- Component sections.
- Loads assignment.

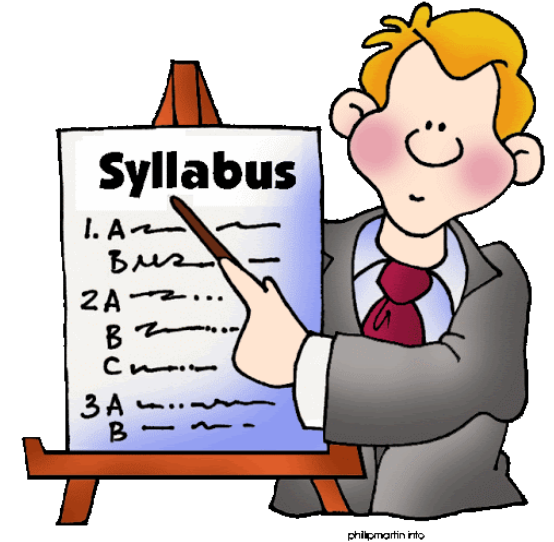


What is the content of this course



➤ Chapter 7 (CSI Bridge Software, cont.):

- Load analysis cases.
- Load combinations.
- Bridge modeling.
- Prestressing modeling and profile assignment.



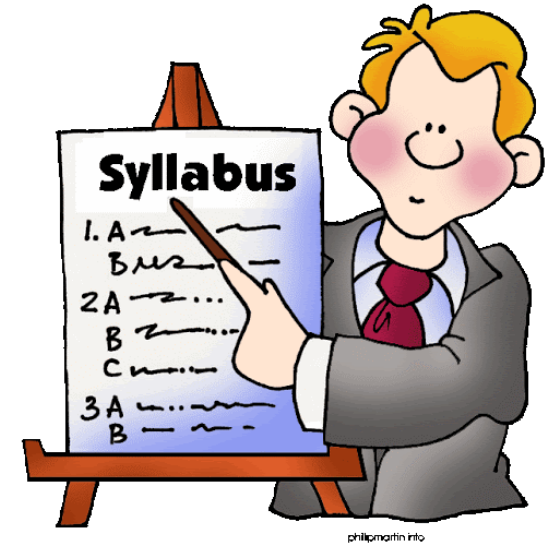
2- Bridge results output:

- Check prestressing stress, design prestressing.
- Get straining actions on bridge deck (shear & torsion)
- Get straining actions on substructure elements.

What is the content of this course

➤ Chapter 8 (AASHTO LRFD and Egyptian Code of Bridges):

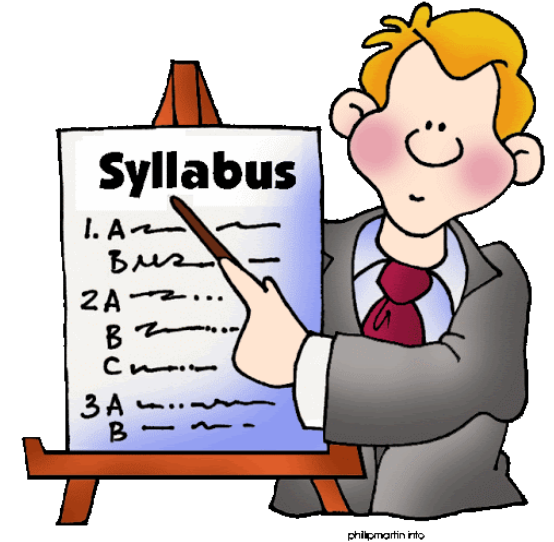
- the codes limits and design method.
- Ultimate design (flexure, shear & torsion) of bridge elements.
- Service design (crack width, deflection & camber).
- Principal of design.
- How to use design tools to design different component.



What is the content of this course

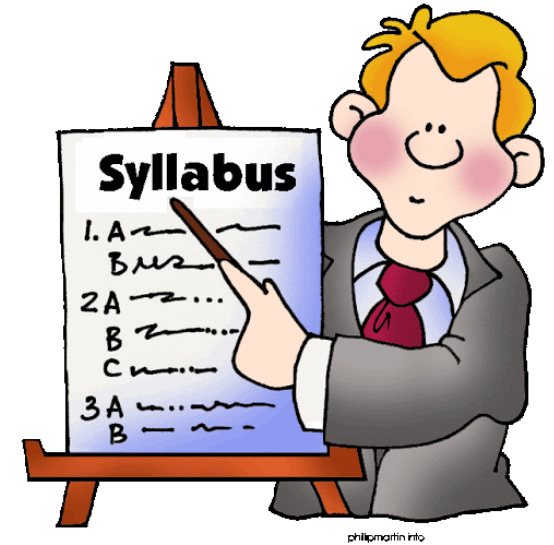
➤ Chapter 9 (Structural Detailed Drawings):

- General notes drawing and what is it's content.
- Reinforcement drawings of bridge element.
- Prestressing profile drawing.
- Prestressing sequence and coupling details.
- Prestressing details.
- Bearing articulation and bearing loads extraction.



What is the content of this course

- Chapter 10 (full project)
- Chapter 11 (tunnels)



Introduction

What is bridges ?

The bridge is,

- a structure to carry traffic over an opening or discontinuity in the landscape.
- Various types of bridge traffic can include pedestrians, vehicles, pipelines, cables, water, and trains, or a combination thereof.
- An opening can occur over a highway, a river, a valley, or any other type of physical obstacle.
- The need to carry traffic over such an opening defines the function of a bridge.



Hover dam bridge, Nevada



Golden gate, san Francisco

Important of the bridges

The bridge,

- is a structure corresponding to the heaviest responsibility in carrying a free flow of transport and is the most significant component of a transportation system in case of communication over spacings/gaps for whatever reason such as aquatic obstacles, valleys and gorges etc.
- Bridges is the KEY ELEMENT in a transportation system.



Interchange bridges

Bridges safety, function and aesthetics



The Bridge Should,

- be “safe, functional, economical, and good looking.” Safety cannot be compromised.
- A bridge must be safe under all of the loads it is designed for. Otherwise, the bridge cannot be opened to traffic.
- Functionality should not be compromised. If four lanes are required, for example, it must provide four lanes.
- But in certain cases, it may still be acceptable if some lane widths are slightly different from the standard width recommended in the specifications, as long as this does not affect safety.

Bridges safety, function and aesthetics

The Bridge Aesthetics,

- are even harder to define.
- For example, the Firth of Forth Bridge in Scotland was often criticized as the world's most ugly structure by some and at the same time lauded as a spectacularly beautiful landmark by others.
- If a bridge is deemed beautiful by most people, then we may be allowed to say that it is beautiful. So, at least at a given time and in a given place, it is possible to say whether a bridge is beautiful or not, based on popular opinion.



the Firth of Forth Bridge, Scotland

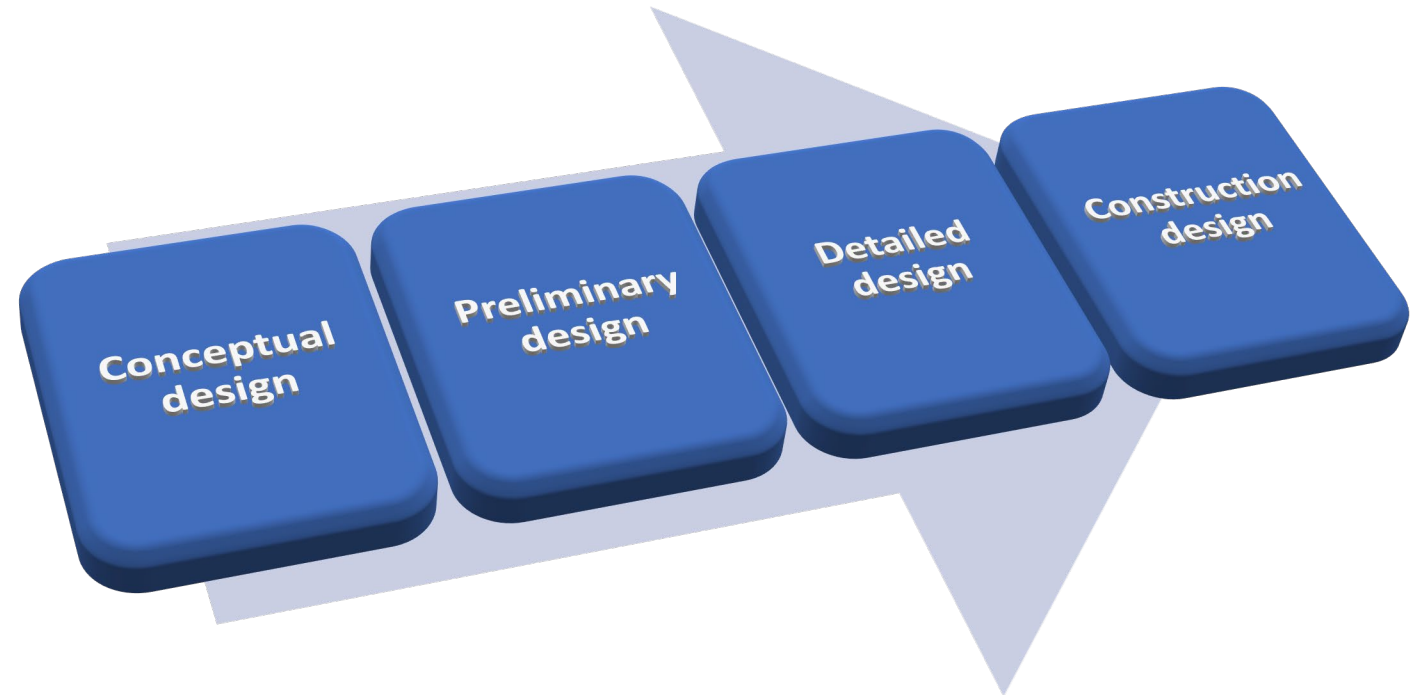
Bridge design mission

Thus,

- the mission of a bridge design may be defined as “to design a safe, functional, and beautiful bridge within the given budget.”
 - Because both economy and aesthetics are relative, there is no “perfect” design, but only a “suitable” design for a bridge.
- 
- Sheikh Zayed Bridge, Abu Dhabi
- If a bridge is deemed beautiful by most people, then we may be allowed to say that it is beautiful. So, at least at a given time and in a given place, it is possible to say whether a bridge is beautiful or not, based on popular opinion.

Four Basic Stages of a Bridge Design,

- The design process of a bridge can be divided into:
 - Conceptual design.
 - Preliminary design
 - Detailed design.
 - Construction design.



Bridge design stages

Conceptual Design,

- is to come up with various feasible bridge schemes and to decide on one or more final concepts for further consideration.

Preliminary Design,

- is to select the best scheme from these proposed concepts and then to ascertain the feasibility of the selected concept and finally to refine its cost estimates.

Detailed Design,

- is to finalize all the details of the bridge structure so that the document is sufficient for tendering and construction.

Construction Design,

- is to provide step-by-step procedures for building the bridge.

Each of the earlier design stages MUST

- consider the requirements of subsequent stages.

For Example,

- For example, the detailed design must consider how the bridge is to be built;
- the preliminary design must consider, in addition, what structural details will look like;
- and, the conceptual design must consider, in addition to all the above, what information the preliminary design will require.

Bridge design stages

This means,

- that a **CONCEPTUAL DESIGN** must sufficiently consider what is required to complete the bridge in the given environment, including providing a general idea of costs and construction schedule as well as aesthetics.
- By “**consider**” we do not mean that we have to actually perform detailed studies on the aforementioned issues during the conceptual design stage, although accumulated engineering experience can help us understand the feasibility of many basic ideas.



Bridge design stages

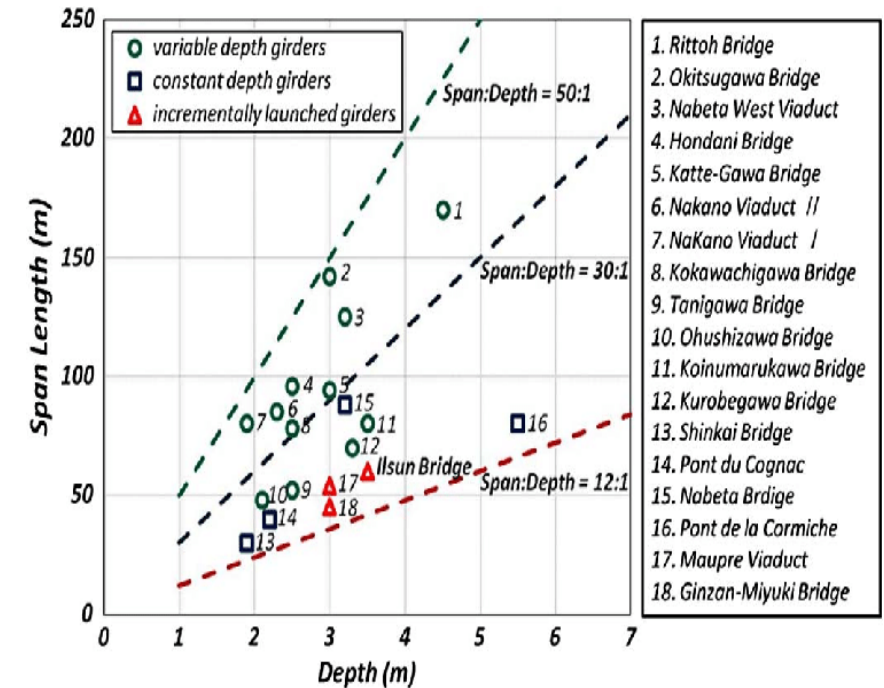


For Example,

- we do not have to conduct a calculation to ascertain that a 50m span prestressed concrete box girder bridge is feasible, if we assume the girder depth to be approximately 2.5 m deep. Rather, our experience accumulated from working on many other bridges shows a medium span prestressed concrete box girder with a depth of 1/20th of the span length can work.

Experience,

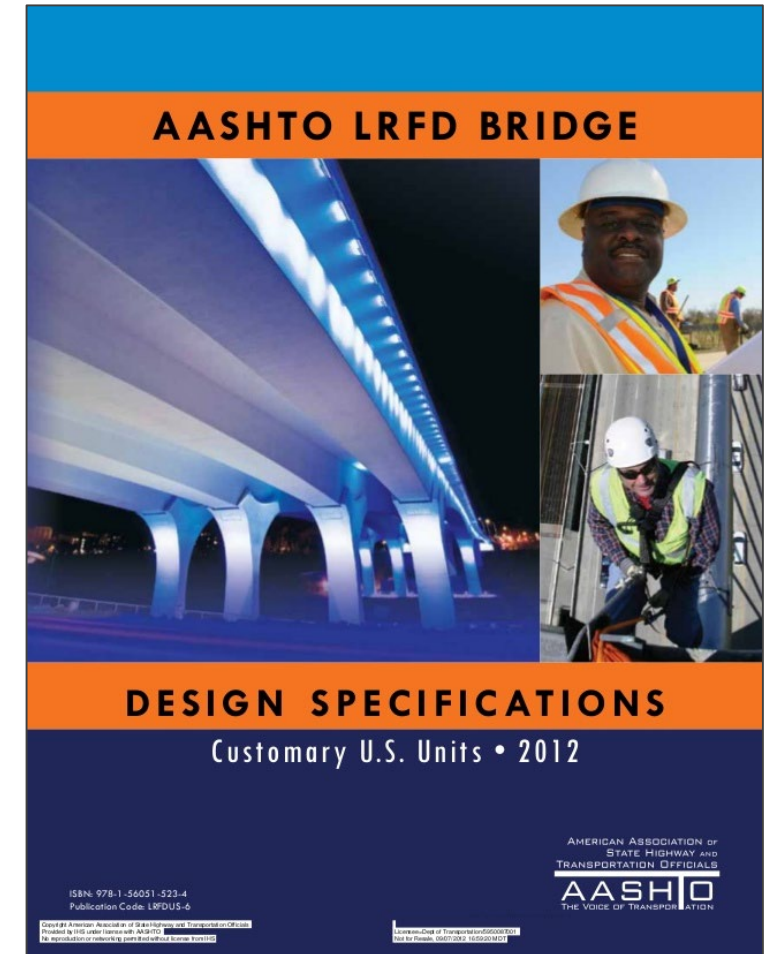
- is of the utmost importance during the conceptual design stage. For this reason, only an experienced engineer should be appointed to perform a conceptual design.



Establishing the Criteria

Codes and Specifications,

- are legal documents.
- This means the design of a bridge must satisfy all provisions in the relevant specifications and codes, such as the “LRFD Bridge Design Specifications” published by the **A**merican **A**ssociation of **S**tate **H**ighway and **T**ransportation **O**fficials (**AASHTO**)



AASHTO 2012

Establishing the Criteria



But Codes and Specifications,

- are not always up to date..
- In our rapidly evolving world, many new ideas and developments may not be reflected in the prevailing specifications and codes because it takes time to modify them, or to introduce new provisions.
- “not to just follow specifications and codes, but to follow the rules of nature.”
- To this we may add that the responsibility of the bridge engineer is not merely to satisfy the requirements of the specifications, but to properly consider the actual conditions including the locality and the people it is designed to serve.

Establishing the Criteria



For example,

- the actual weight of trucks.
- Overloaded trucks are not uncommon in some localities.
- Overloaded trucks can cause overstress in the structure and reduce the fatigue life of the bridge.
- For example, the fatigue life of a welded steel detail is approximately inversely proportional to the cube of the stress range. If trucks are regularly overloaded to 150% of their design axle loads, this may reduce the service life of a steel detail to < 30% of its design life. Consequently, a 100-year design life may be reduced to 30 years.

Establishing the Criteria



Project-Specific Design Criteria,

- A bridge is designed to satisfy a given function under given environmental conditions and constraints.
- The design must also follow the prevailing specifications and codes.
- These design criteria represent the constraints of the bridge we want to build.
- The aim of the conceptual design is to come up with the most suitable bridge scheme that can satisfy all the given design criteria.



Bridge Types

Our first step,

- is to consider the most suitable bridge type.
- We can group all bridges in the world into four basic types:
 1. girder bridge.
 2. arch bridge.
 3. cable-stayed bridge.
 4. suspension bridge.



Girder type bridges

Bridge Types

Common wisdom,

- suggests that girder bridges and arch bridges are good for short to medium spans (till 150 m span).
- whereas cable-stayed bridges are good for medium to longer spans (till 750 m span).
- and suspension bridges are good for very long spans (for spans more than 1000 m span).
- Based on this assumption, some engineers established rules to assign a span range for each of these bridge types.



Cable stayed bridge



Suspension bridge

Over time,

- with improvements in construction materials and advancements in construction equipment and technique, the reasonable span length of each bridge type has significantly increased.
- However, an engineer should not be restricted by these assumptions. Instead, it is important for engineers to understand what the actual limits of each bridge type are, based on his or her understanding of the latest construction materials and equipment available at the time of construction.



Arch bridge

Over time,

- with improvements in construction materials and advancements in construction equipment and technique, the reasonable span length of each bridge type has significantly increased.
- However, an engineer should not be restricted by these assumptions. Instead, it is important for engineers to understand what the actual limits of each bridge type are, based on his or her understanding of the latest construction materials and equipment available at the time of construction.

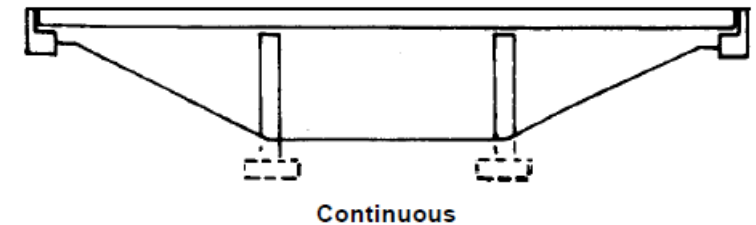
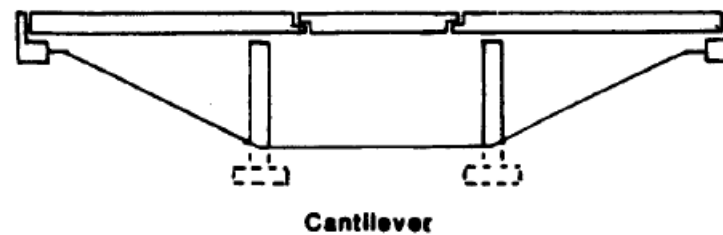
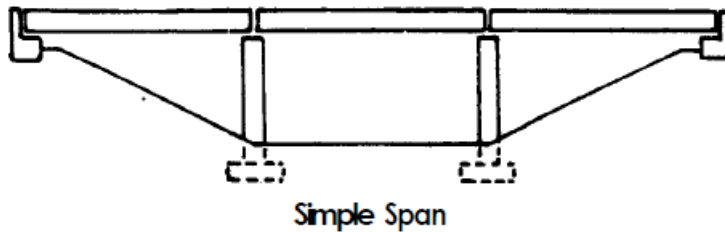


Arch bridge

Statical System of different girder bridge types

Simple, cantilever, and continuous span types,

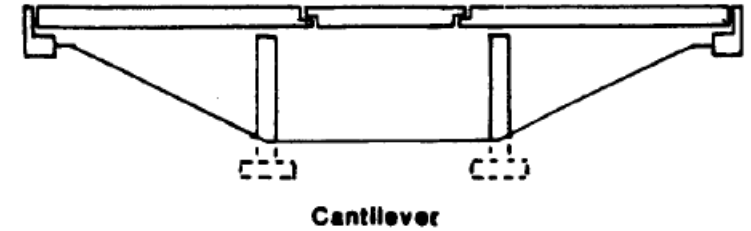
- **CONTINUOUS STRUCTURES** with variable moments of inertia for slabs, stringers, and girder systems require the least material.
- However, in the shorter span range the labor cost of constructing variable sections often offsets the material savings.



Statical System of different girder bridge types

Simple, cantilever, and continuous span types,

- In the past the use of **CANTILEVER ARMS** and suspended spans rather than continuous structures resulted from fear of the effect of differential settlement of supports.
- It should be recognized that these effects can now be readily considered by proper use of analytical methods and current knowledge in soil mechanics and foundation engineering.



Statical System of different girder bridge types

Simple, cantilever, and continuous span types,

- In the longer span range of slab, stringer, and girder-type bridges, the use of continuous structures with variable moments of inertia (variable depth) is strongly recommended.
- It should also be recognized that the designer may sometimes take advantage of the economy of a combination of bridge types.
- Short approach spans of slab or box beam construction may be combined with a single main arch span or with long box girder spans.



Variable depth bridge

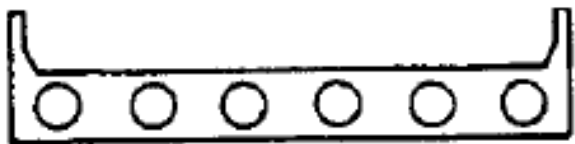
Bridge Deck Cross Sections

Slab type,

- Slab-type concrete bridges consist of solid or voided slabs which span between abutments and intermediate piers.
- The use of **slab bridges** should be considered for spans up to **25 m**



Solid Slab



Voided Slab

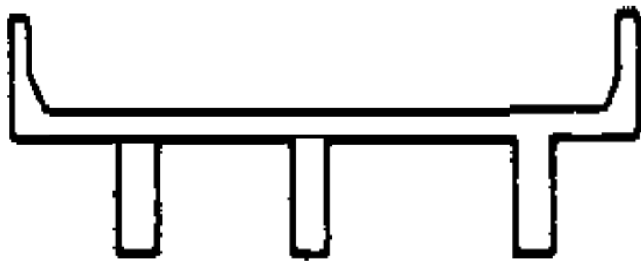


Slab Type Bridge

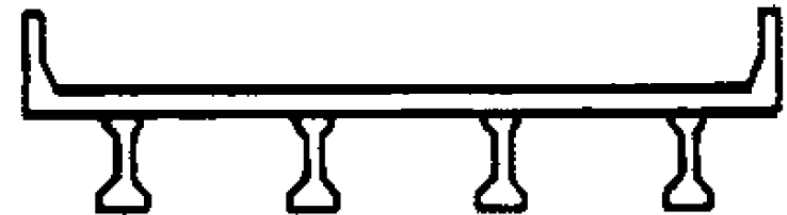
Bridge Deck Cross Sections

Stringer (beam) type,

- The main structural elements of this type of concrete bridge consist of a series of parallel beams or stringers which may or may not be connected with diaphragms.
- The stringers support a reinforced concrete roadway slab which is generally constructed to act as the top flange of the stringer.



Cast-in-place



Precast

Bridge Deck Cross Sections

Stringer (beam) type,

- Use of **stringer bridges** should be considered for spans ranging from about **(6m to 35m)**.
- Stringers generally are spaced from (1.8m to 2.8m) on centers.
- Main reinforcement or prestressing is located in the stringers.
- When the stringers are prestressed, the concrete roadway slab may be reinforced in two directions.

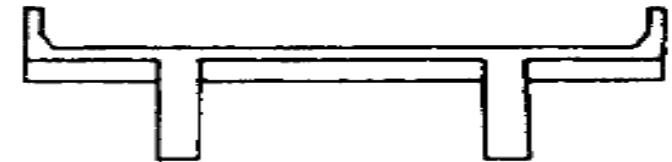


Cast in place stringer type bridge

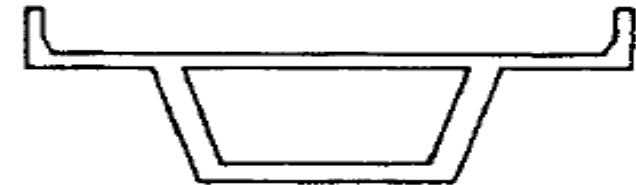
Bridge Deck Cross Sections

Girder type,

- This type of concrete bridge consists of either longitudinal girders carrying cross beams that in turn carry the roadway slab,
- Or longitudinal box girders whose bottom slab functions as the bottom flange of the girder.
- In both types the top slab serves the dual function of being the flange of the girder and the roadway slab of the bridge.



Solid Web



Box Girder

Girder type (Solid web girders),

- This type of bridge differs from the stringer type in that the reinforced concrete roadway slab spans longitudinally and is supported on cross beams spaced apart (2.4 to 3.6 m).
- In general only two girders are used.
- It is a feasible solution where large overhangs of the deck are desirable, and where the depth of construction is not critical.
- Spans of up to (55 m) have been built.

Bridge Deck Cross Sections

Girder type (Box girders),

- These girders may consist of a single cell for a two-lane roadway, multiple cells for multiple-lane roadways,
- Or single or multiple cells with cantilever arms on both sides to provide the necessary roadway width, and to reduce the substructure cost and minimize right of way requirements.
- This type of concrete bridge may have economical span lengths from less than (30 to 210 m).
- In the longer span range, variable depth deck is used.

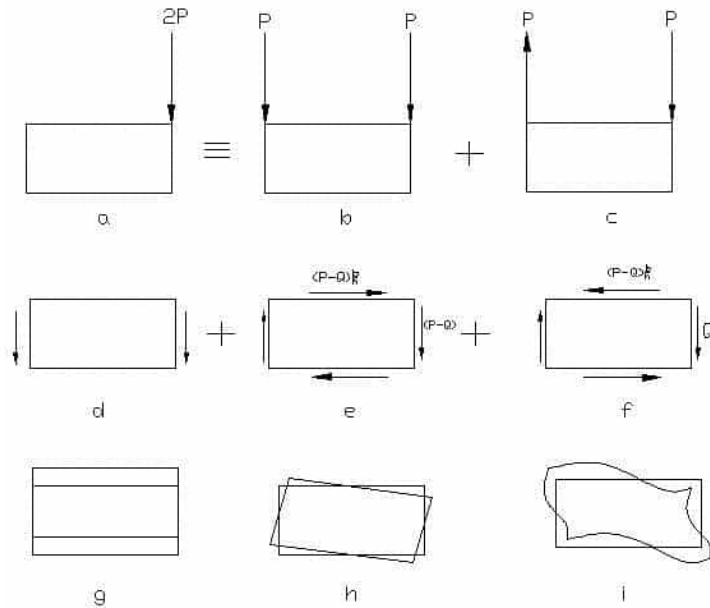


Box girder

Bridge Deck Cross Sections

Girder type (Box girders),

- Because of their superior torsional rigidity, box girders are especially recommended for use on curves or where torsional shearing stresses may be developed.



Torsion rigidity of box girder



Curved box girder

In the design of a bridge,

- construction and erection considerations may be of paramount importance in the selection of the type of bridge to be built.
- Also, the experience of the available contractors, the ability of local material suppliers to furnish the specified materials.
- the skilled labor required for a particular structure type.
- The most economical bridge design is one in which the total cost of materials, labor, equipment, and maintenance is minimized.

Cast-in-place and Precast concrete,

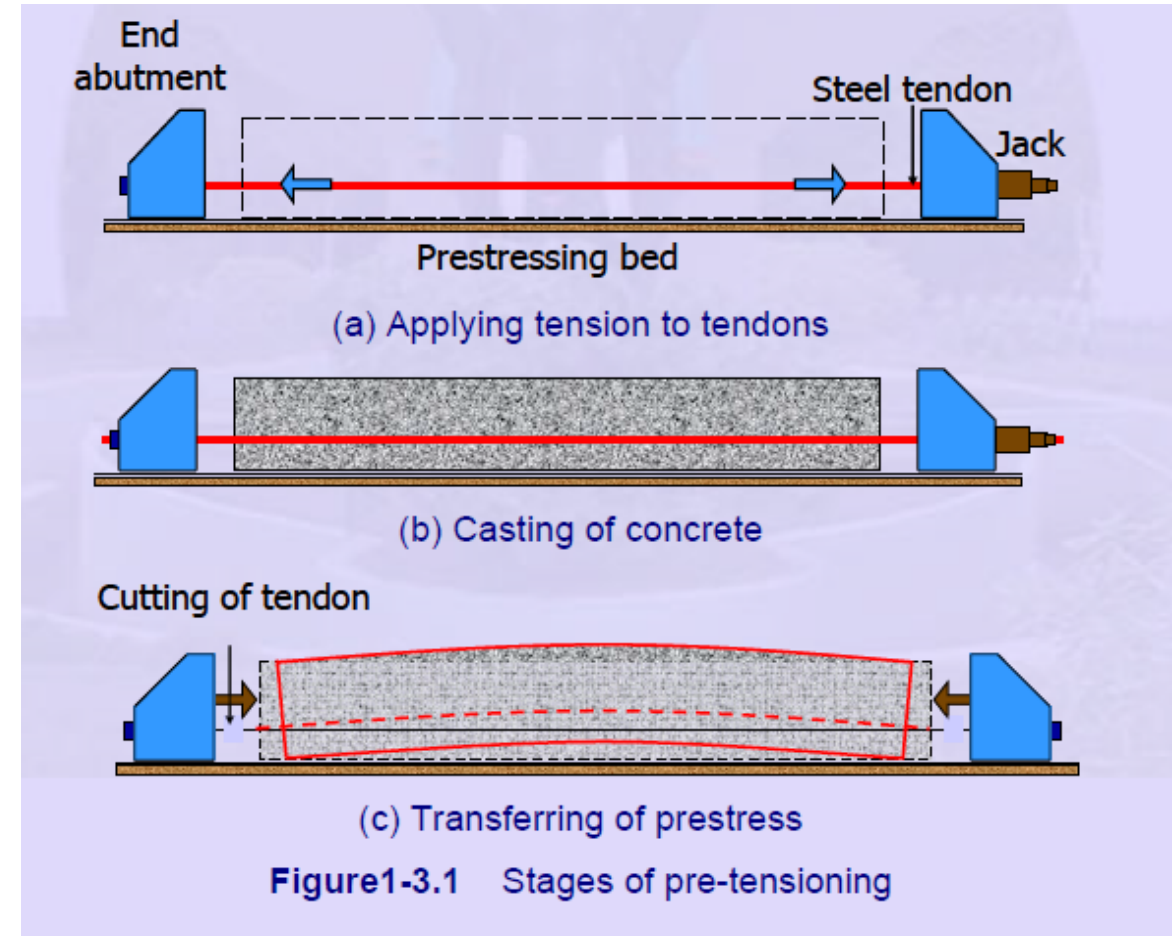
- The decision to use or not to use precast concrete could be influenced by the availability of existing precast plants within transport distance.
- Precast concrete may be competitive in areas without existing pre-casting plants when a **large number of similar components** are required.
- In large projects, a pre-casting plant located at the site should be considered to see if it would prove more economical.
- For grade separation structures, if traffic problems are not a controlling factor, cast-in-place structures are generally more economical when the height of falsework is less than (9 to 12 m) high.

Reinforced, partially prestressed, and prestressed,

- The possible use of pre-tensioning or post-tensioning should be considered during the planning stage of a bridge project.
- In many cases the greatest economy can be realized by allowing the Contractor the option of using pre-tensioned, post-tensioned, or a combination of both.
- In these cases, the specifications should require submittal by the Contractor of proper design data.

Pre-tensioning VS Post-tensioning

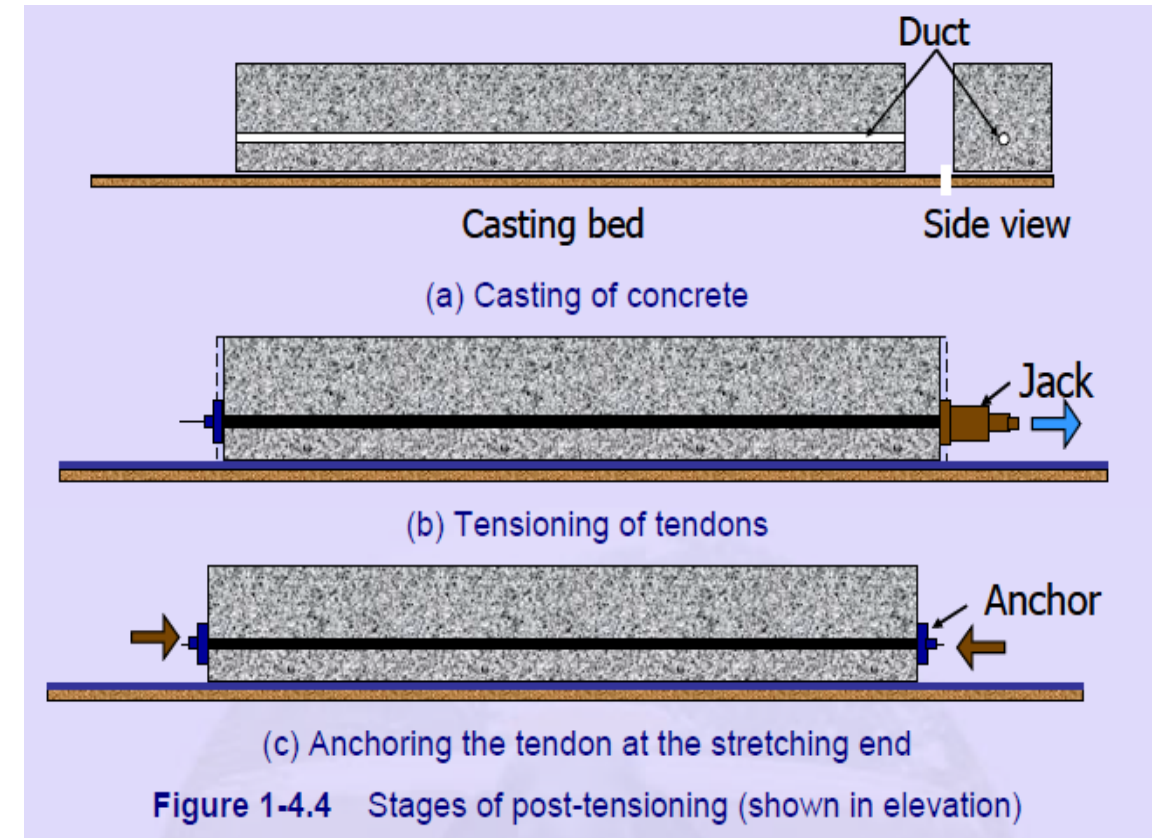
- Pre-Tensioning
- In this method the tendons(group of wires) are pulled between two end bulkhead prior to casting . This pre-stress is later transferred to concrete due to bonding between the concrete and tendons .



Pre-Tensioning process

Pre-tensioning VS Post-tensioning

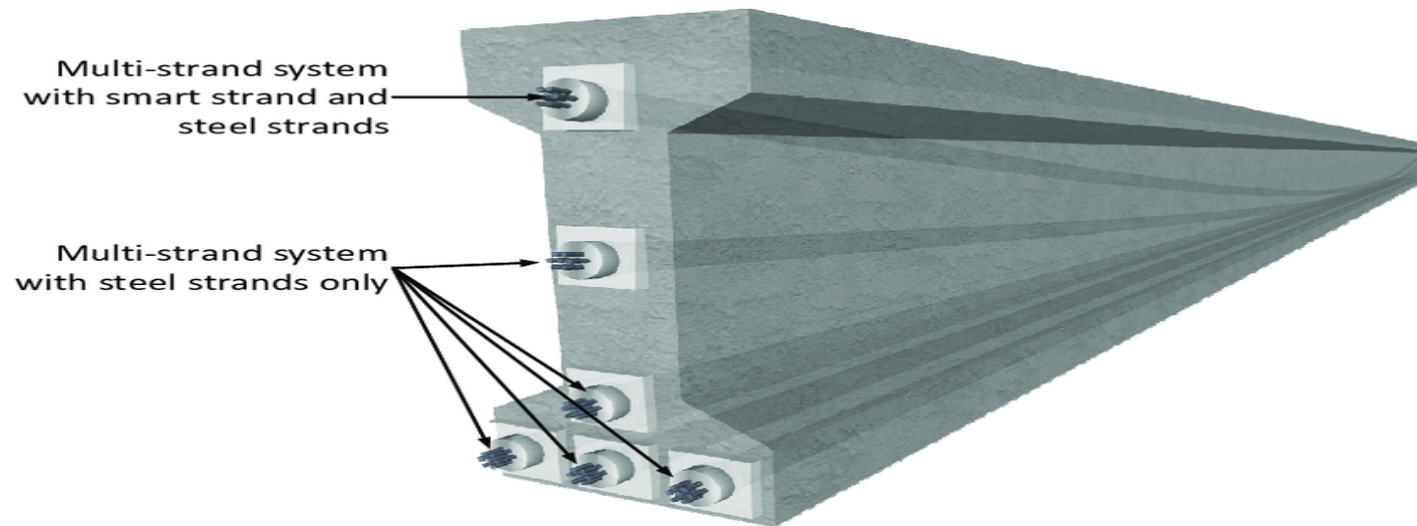
- Post-tensioning
- In this process first the casting of structure is done and later the tensioning is done. Stressing in Post-Tensioning is done in two-stages in which the order of selection of tendon is done based on the drawing provided.



Post-Tensioning process

Pre-tensioning VS Post-tensioning

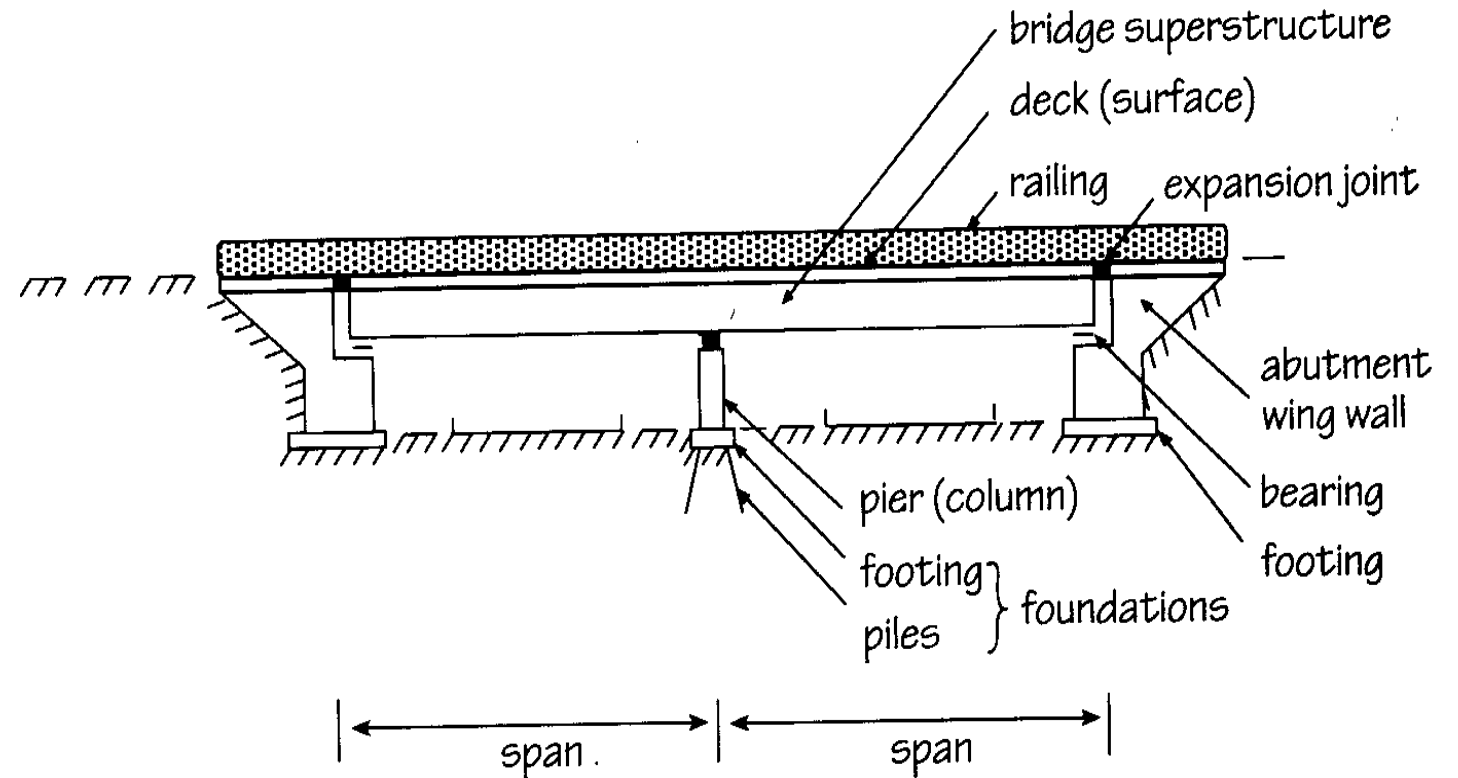
- Post-tensioning
- This tendons are installed via duct pipe in the structure (PSC Girder) which after stressing process are sealed with a mix of cement + water + intraplaster (sika or civax-100). This process is known as **Grouting**.



Bridge component definitions

Components definition

- Sub Structure
- Piles.
- Footing.
- Pier.
- Abutment.
- Bearing.



TYPICAL BRIDGE ELEMENTS

Bridge component definitions



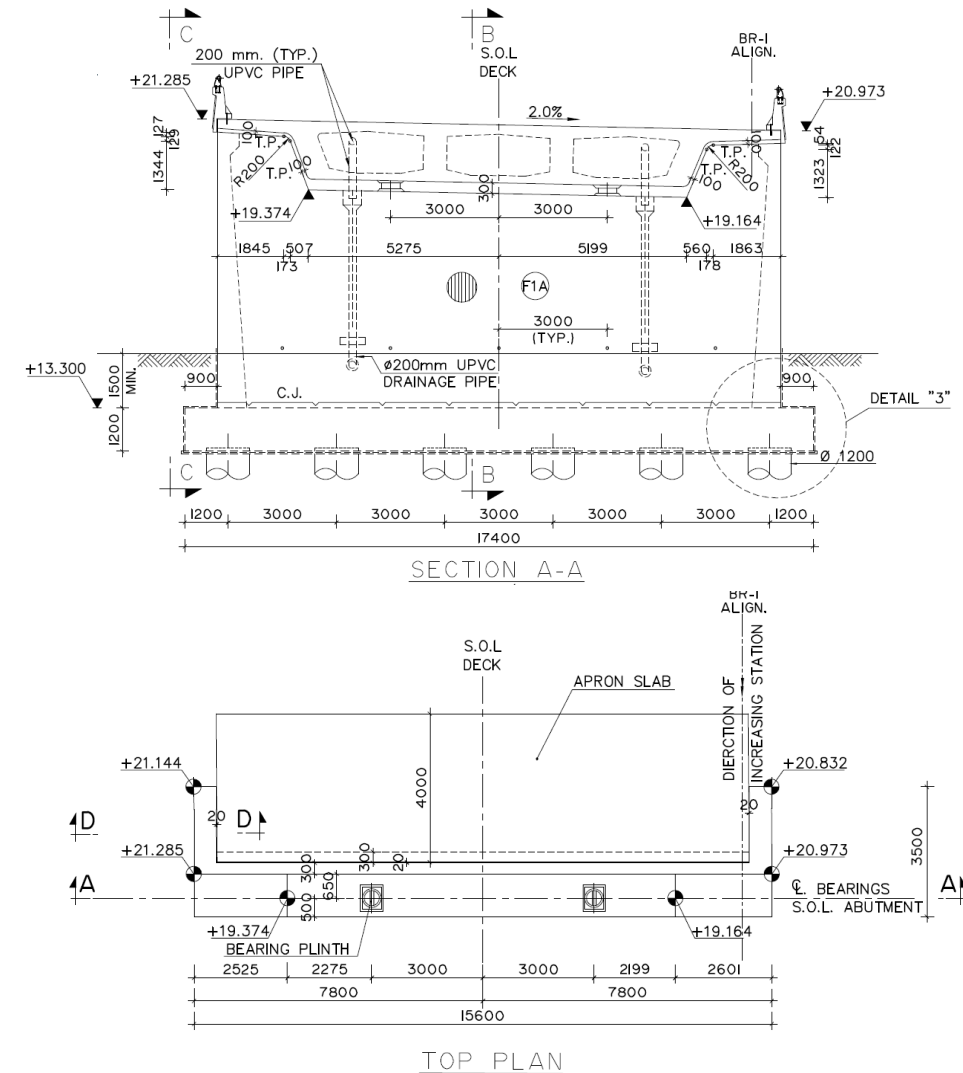
Components definition

- Sub Structure
- The substructure consists of all of the parts that support the superstructure.
- The main components are abutments or end-bents, piers or interior bents, footings, and piling.

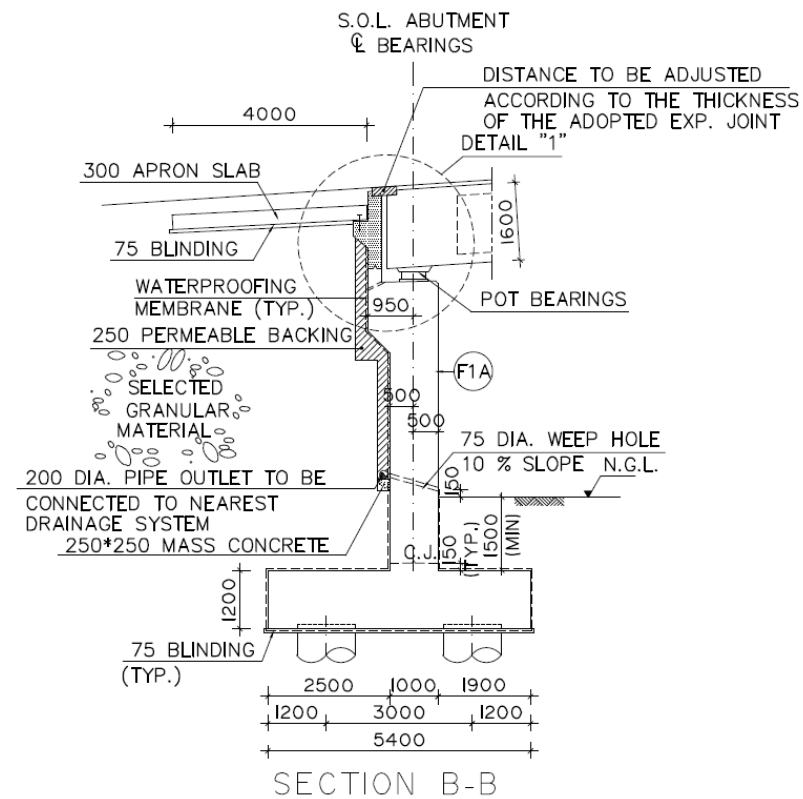
Bridge component definitions

Components definition

- Abutment
- Abutments support the extreme ends of the bridge and confine the approach embankment, allowing the embankment to be built up to grade with the planned bridge deck.



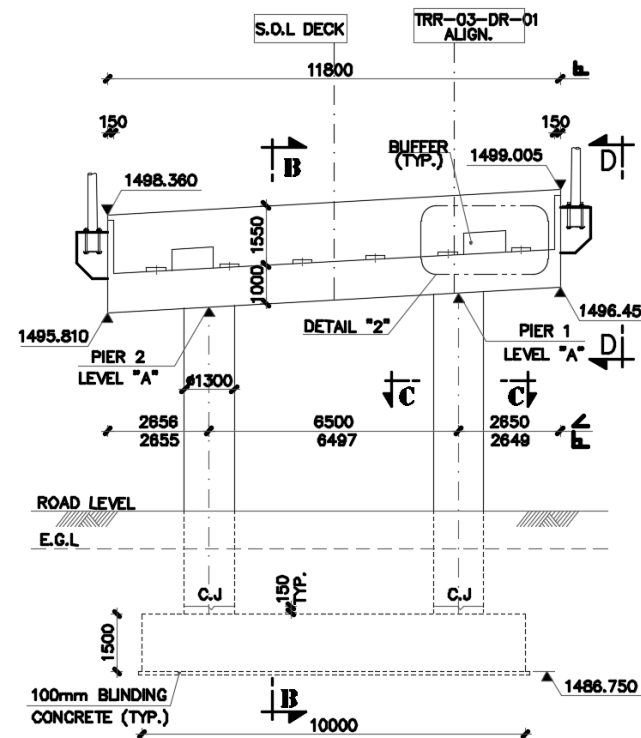
- Abutment



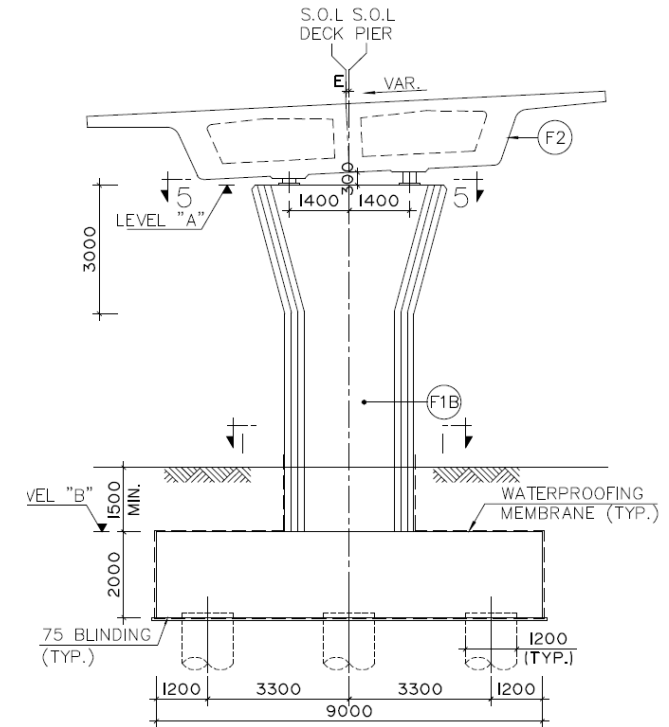
Bridge component definitions

Components definition

- Pier / Bent
- When a bridge is too long to be supported by abutments alone, piers or interior bents are built to provide intermediate support.
- Although the terms may be used interchangeably, a pier generally is built as a solid wall, while bents are usually built with columns.



Bent

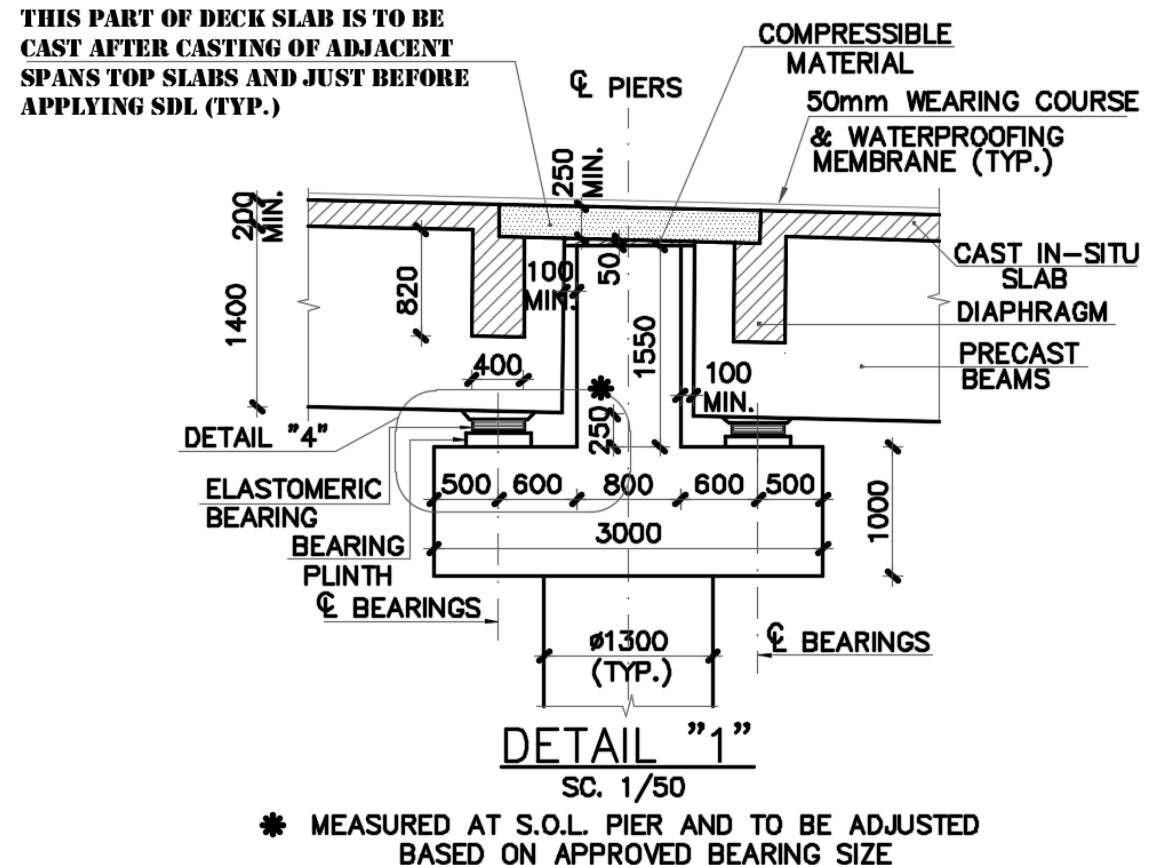


Pier

Bridge component definitions

Components definition

- Pier Cap & pedestal
- The top part of abutments, piers, and bents is called the cap.
- The structural members rest on raised, pedestal-like areas on top of the cap called the bridge seats.

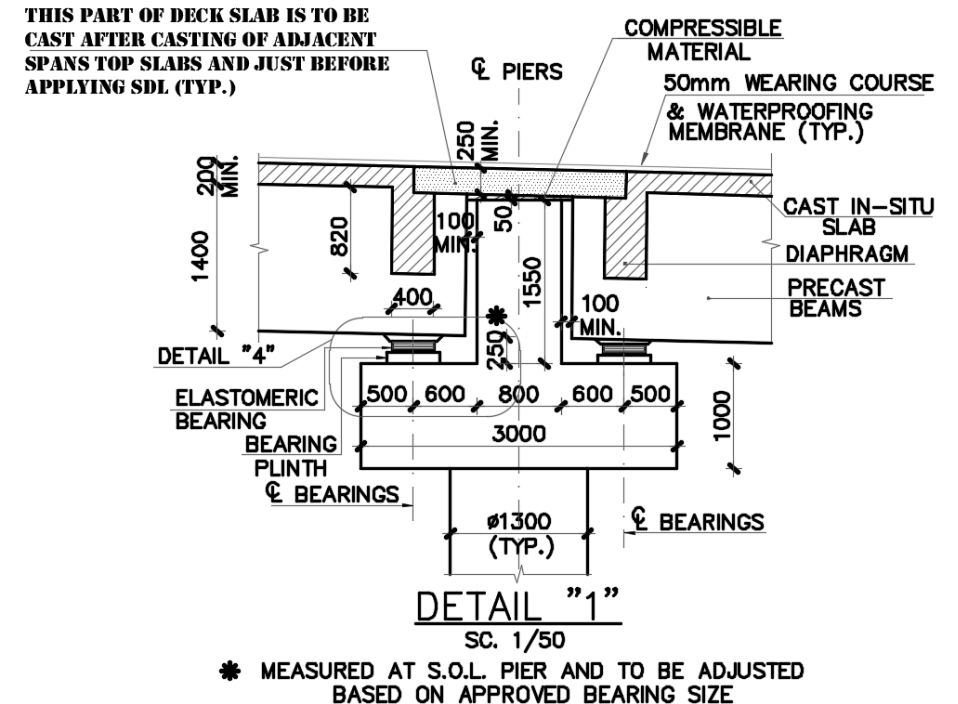
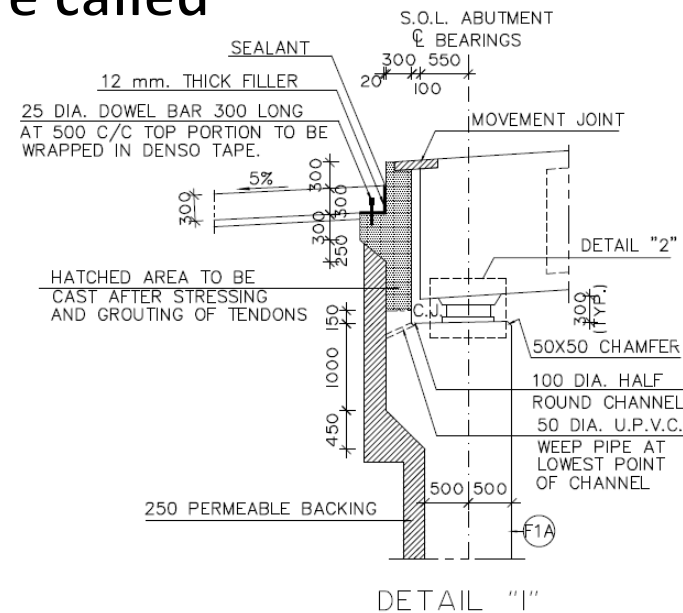
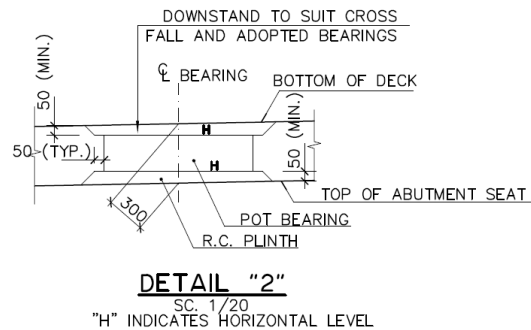


Pier Cap & pedestal

Bridge component definitions

Components definition

- Bearings
- The devices that are used to connect the structural members to the bridge seats are called shoes or bearings.



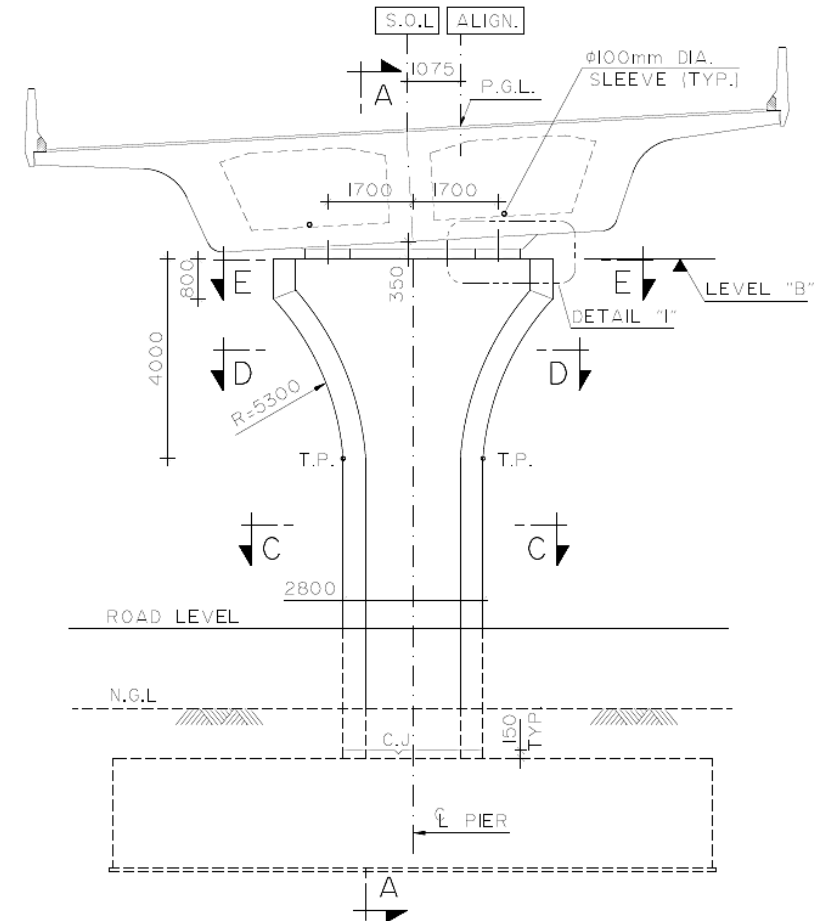
Bearings in beam type bridge

Bearing @ abutment

Bridge component definitions

Components definition

- Shallow Footings
- Abutments, bents, and piers are typically built on spread footings. Spread footings are large blocks of reinforced concrete that provide a solid base for the substructure and anchor the substructure against lateral movements.

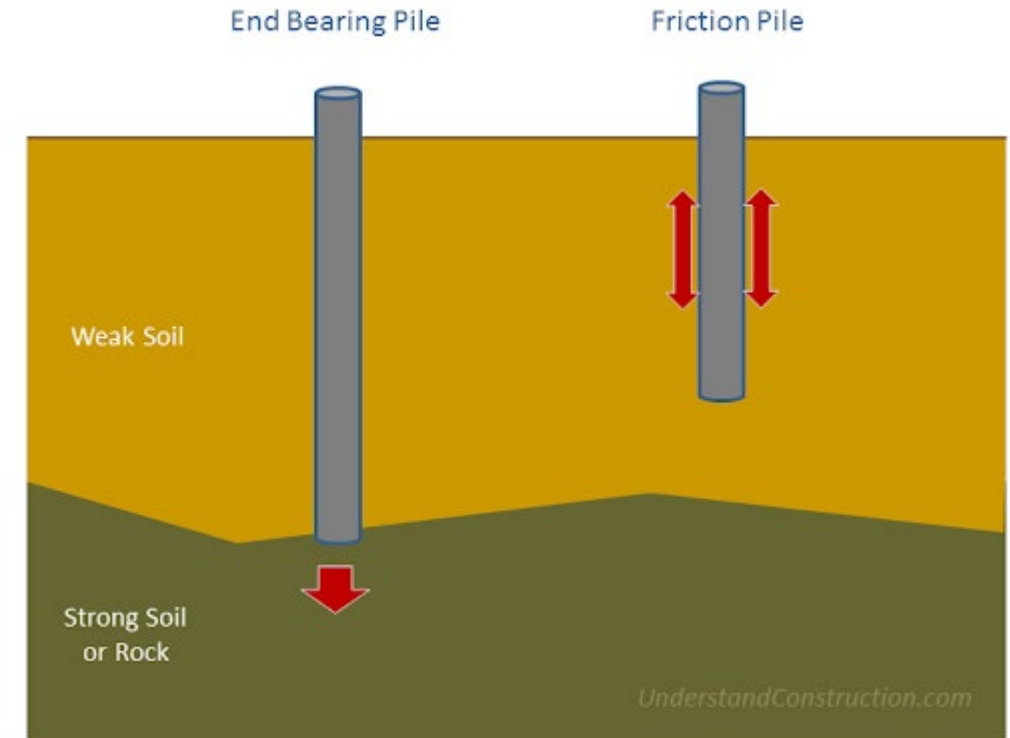


Shallow footing

Bridge component definitions

Components definition

- Pile
- These load-bearing members are driven deep into the ground at footing locations to stabilize the footing foundation. Piling transmits loads from the substructure units down to underlying layers of soil or rock.

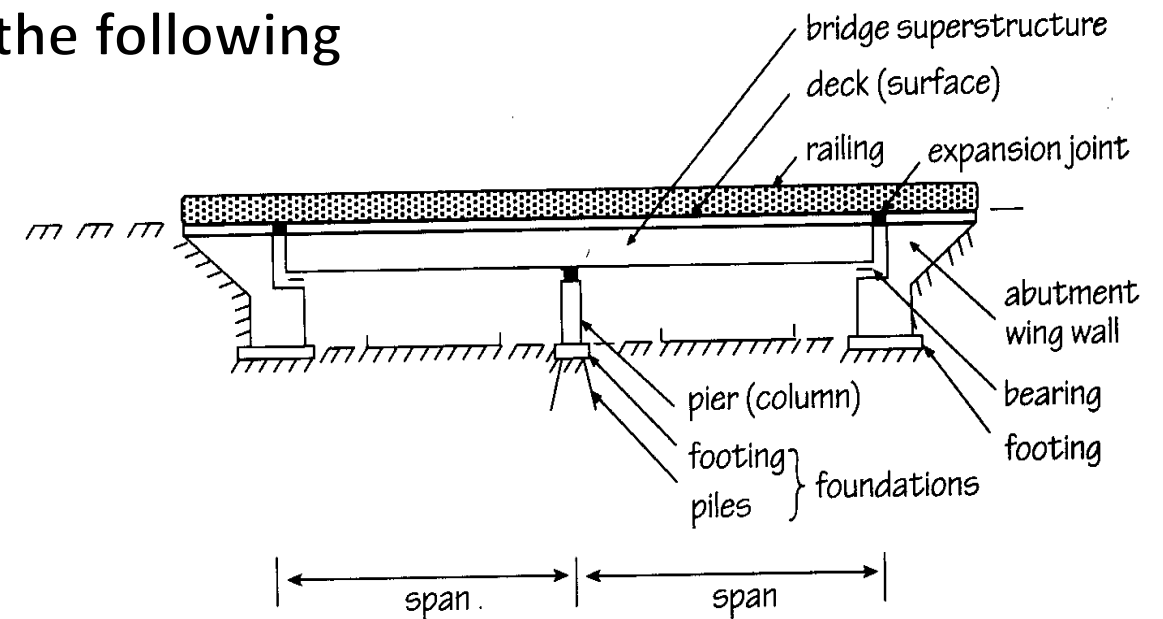


Pile types

Bridge component definitions

Components definition

- Super Structure
- The superstructure consists of the components that actually span the obstacle the bridge is intended to cross and includes the following
- Deck girder.
- Deck slab.
- Diaphragms.
- Railing.



TYPICAL BRIDGE ELEMENTS

Bridge component definitions

Components definition

- Deck
 - The deck is the roadway portion of a bridge, including shoulders. Most bridge decks are constructed as reinforced concrete slabs.
 - Bridge decks are required to conform to the grade of the approach roadway so that there is no bump or dip as a vehicle crosses onto or off of the bridge.

